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Reassessing Weapons System Operational Test and Evaluation Methods

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REASSESSING WEAPON SYSTEM OPERATIONAL TEST & EVALUATION METHODOLOGIES

LTC Thom Crouch
GSBPP, NPS
January 22, 2004

RESEARCH QUESTIONS

P: How well do current DoD test methodologies support assessing a weapon systems true cost and performance characteristics?

S1: Can/should cost, operational effectiveness and suitability be assessed independent of one another?

S2: Do current test methodologies adequately address weapon systems total ownership cost (TOC)?

S3: Are there critical cost and performance variables absent in DoD's current evaluation logic?

S4: Are there different test methodologies that might be better suited for the testing of today's weapon systems?

THE ROOT ISSUE

The Pentagon has to become more diligent in representing the true costs of weapons system development, Pentagon acquisition chief Pete Aldridge told members of the House Armed Services Committee panel on research and development yesterday. "We have to be realistic in how we cost programs rather than being too optimistic,"

Pete Aldridge
Defense Acquisition Executive
July, 27 2001

CURRENT STATE

COST:

- Weapon system cost estimates are currently conducted independently by Service and DoD agencies

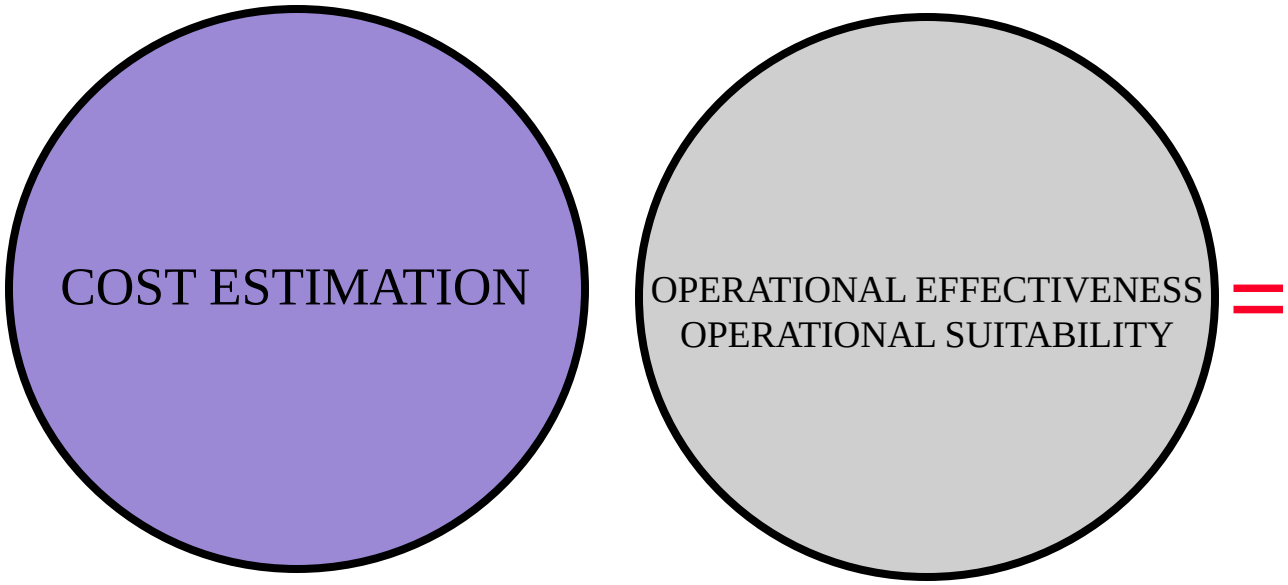
T&E:

- Weapon system performance is independently assessed by Service OTAs and characterized in terms of Operational Effectiveness and Operational Suitability

COST - T&E INTERACTION

COST ANALYST

T&E EVALUATOR



Cost Estimates & Operational Capability Generated and Assessed Independent of One Another

Two Independent Types of Organizations
Primarily Two Independent Processes

THE RACING ANALOGY

• You've just become an owner in the new NASCAR Series and you're determined that your team is going to be a winner.
• This new NASCAR Series is based on TEAM racing which dictates that each team must maintain 6 cars on the track at all times throughout each 500 mile race. Pit stops for gas and tire changes are considered being on the track. Any stop for maintenance is considered off the track and to remain in the race the TEAM must replace the broken car by another team car.
• Any car that crashes may be replaced by another TEAM car while the field is still under Yellow Flag Conditions. If you don't have a replacement car to keep your TEAM at 6 cars you're eliminated from competition.
• The TEAM of 6 finishing cars with the lowest combined time wins the race.
• There are 20 races per season, 1 per week for 20 consecutive weeks.
• You are assigned a point total commensurate with your finishing place for each race. The TEAM with the lowest point total at the end of the year is declared the winner. Since there are 25 TEAMS competing, any TEAM that does not successfully complete a race is given 25 points for that race.
• As the owner you are responsible for all costs associated with the design, development, production, operations and retirement of all activities associated with your TEAM operation.

MORE RACING DETAILS

- So you surround yourself with a group of newly graduated NPS engineers and begin to plan your racing team. Although you're a wealthy individual, both winning AND cost are extremely important and you're determined not to let this adventure bankrupt you.

- Your NPS engineers prove to be extremely brilliant and pepper you with such intuitive questions as:

1. How fast do you want this thing do go?
2. How many cars do we need to build to ensure we can keep 6 cars on the track for the entire season?
3. How many pit stops can we make per race and still be competitive?
4. How often do drivers crash one of these things?
5. How many hours per week do you plan on driving each car?
6. How many people will you need to keep all these cars running?
7. At what point do we declare a car un-repairable and replace it?
8. How many spare parts are we going to need to sustain us through the season?
9. How do you want to distribute your money between, design, development, production, operational race support and system retirement?
10. How do we get all these cars, crews and equipment from one race track to another?
11. How are we going to test our progress to see if we are meeting our objectives?
12. At what point will you know if you can really afford this adventure?

- Your head begins to throb as your realize this is really tough stuff. One of your NPS Lieutenants looks at you, smiles and says, "Boss, just be glad we're not having to integrate weapon systems on these cars and take them off to war."

COST ANALYSIS SOURCES

Questions:

- Who performs T&E and cost analysis within DoD?
- What methodologies do they use?
- How integrated are cost analysts with the T&E organizations in support of their data needs?

Cost Analysis Organizations

Army

Cost and Economic Analysis Center (CEAC)
5611 Columbia Pike; Falls Church, VA 22041 - 5050
(703) 756 - 0219

Navy

Naval Center for Cost Analysis (NCCA)
Crystal Gateway North, Suite 400
1111 Jefferson Davis Hwy; Arlington, VA 22202
(703) 604 - 0308

Air Force

Air Force Cost Analysis Agency (AFCAA)
Crystal Gateway North, Suite 403
1111 Jefferson Davis Hwy
Arlington, VA 22202
(703) 604 - 0387

OSD

Cost Analysis Improvement Group (CAIG)
Room 2E314; Pentagon, Washington DC , 20301
(703) 697 - 0221

DOD COST ANALYST

Cost Analysis Improvement Group

The CAIG provides independent cost and risk assessments and analyses of Major Defense Acquisition Programs and is required to do so by law. Its specific responsibilities are detailed in Department of Defense Directive (DoDD) 5000.4. A few of the more important duties of the CAIG follow: ☐

- estimate and report the life-cycle cost of each Category ID and certain Category IC programs at Milestone II and III. Estimates and reports dealing with Category ID programs are directed to the USD (AT&L). Estimates and reports dealing with Category IC programs are provided to official to whom the USD(AT&L) has delegated milestone approval authority;
- provide ad-hoc estimates and analyses on programs that are not milestone reviews upon the request of the USD(A);
- review the estimates presented and develop uniform criteria to be used by all DoD units making such cost estimates;
- prepare independent cost estimates based on historical cost experience;
- compare the acquisition cost of new programs versus procurement of upgraded versions of existing systems;
  formally introduce most-likely cost estimates and the realistic consideration of potential cost problems into DoD痴 acquisition decision process;
- improve the collection of system acquisition information for estimating future system cost

COST ESTIMATION METHODOLGIES

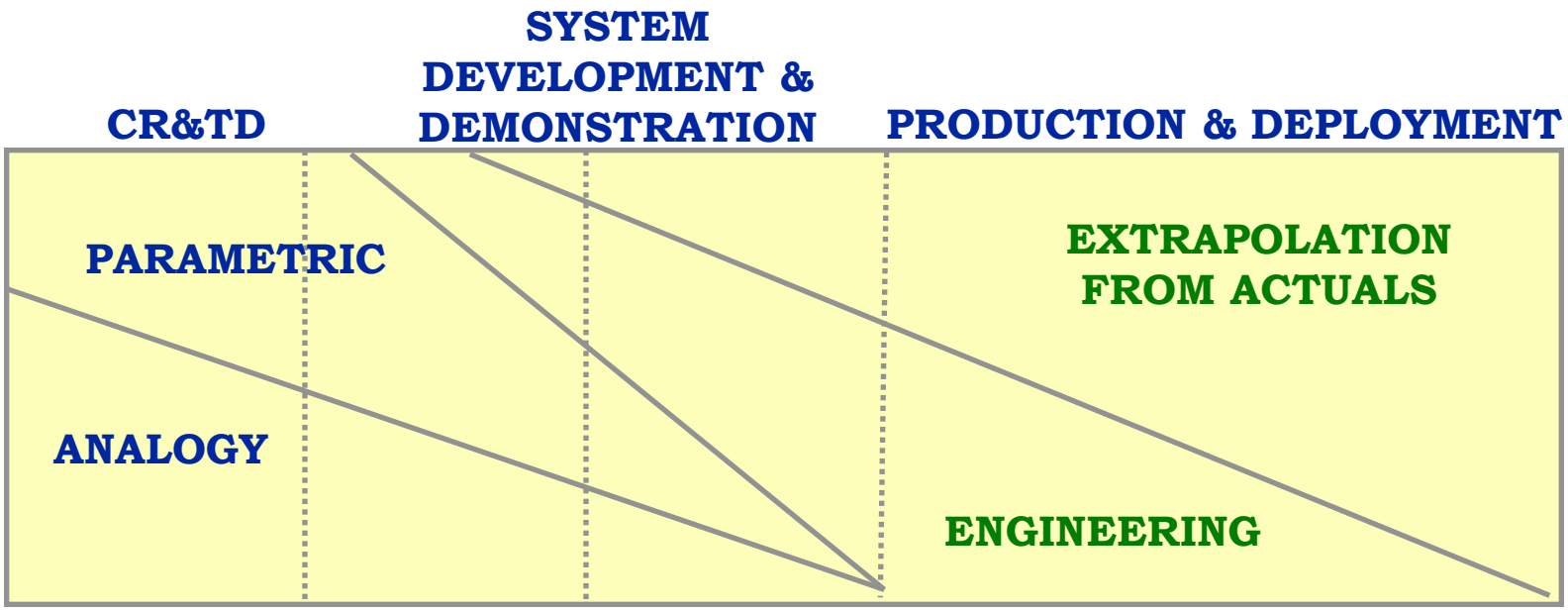
- **Expert Opinion**
- **Analogy:** Comparison of a new system with "similar" existing systems for which there is accurate cost and technical data
- **Parametric:** Uses a data base of like elements and generates an estimate based upon a particular performance or design characteristic
- **Engineering:** "Bottom-Up" compilation from lowest level in the WBS
- **Extrapolation:** Based on data from earlier/previous units same system

COST ESTIMATING

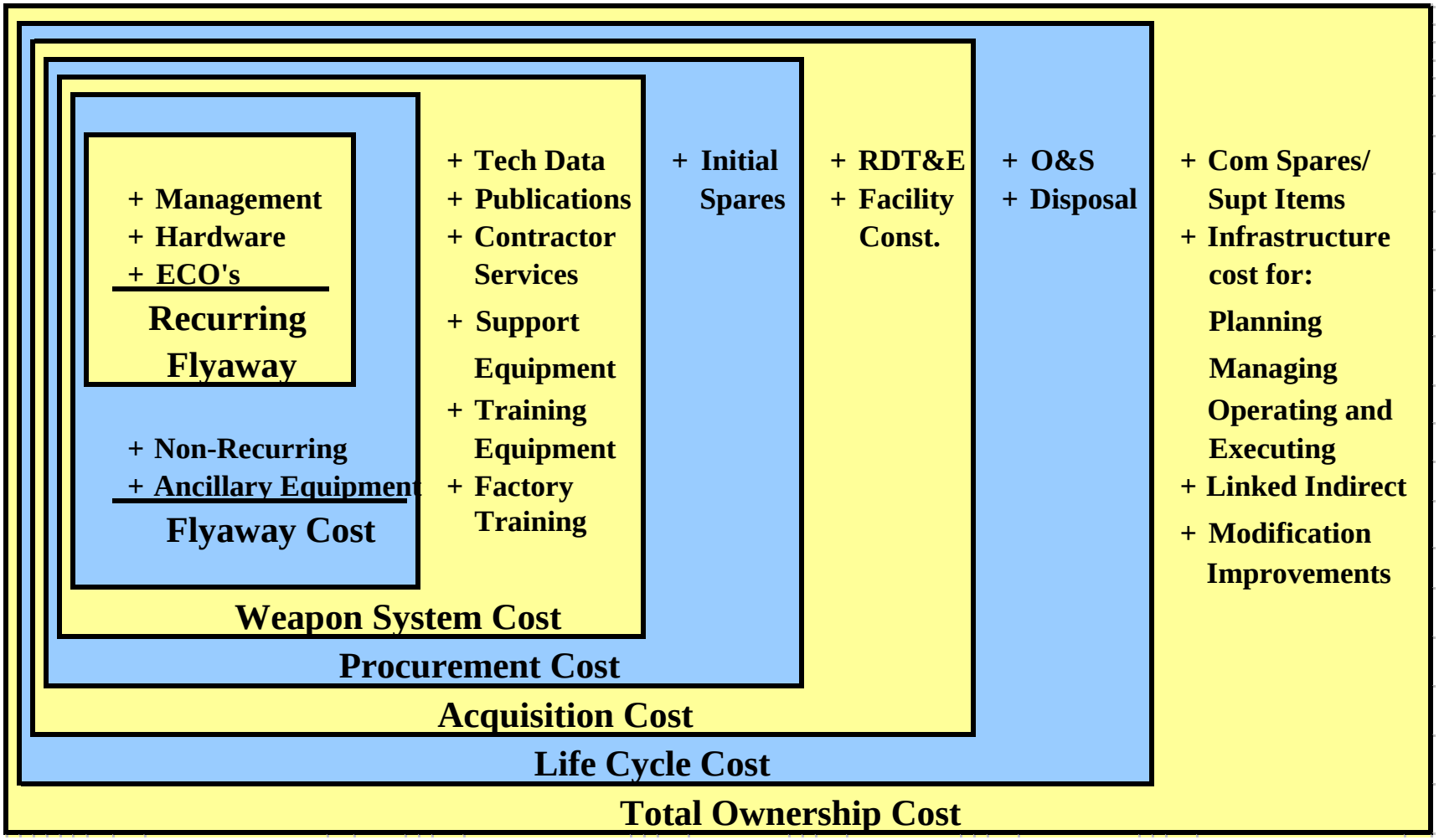
GROSS ESTIMATES

DETAILED ESTIMATES

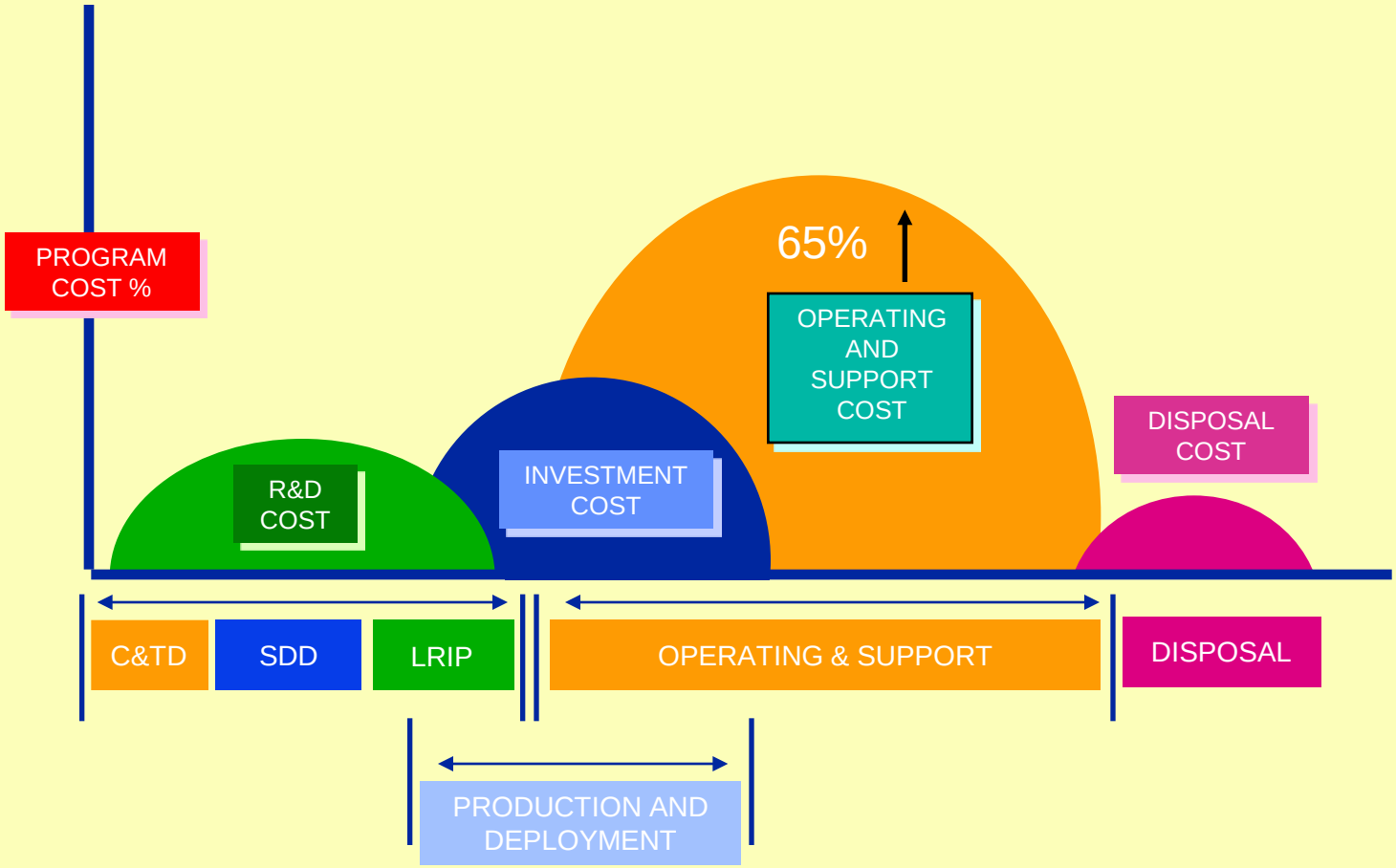
DESIGN MATURITY



Total Ownership Cost Composition



SYSTEM LIFE CYCLE COST
BY LIFE CYCLE COST CATEGORY



CURRENT T&E ROLE

TEST & EVALUATION DEFINITION

TEST

- A Program, Procedure, or Process to Obtain, Verify or Provide Data for Determining the Degree to Which a System (Component) Meets, Exceeds, or Fails to Meet Its Stated Objectives

EVALUATION

- The Review, Analysis and Assessment of Data Obtained From Testing or Other Sources (to Determine the Degree...)

TEST AND EVALUATION

- Process by Which a System or Components Are Compared Against Requirements and Specifications Through Testing. The Results Are Evaluated to Assess Progress of Design, Performance, Supportability, Etc.

OPERATIONAL TEST & EVALUATION (OT&E)

Conducted to:

- Evaluate a System Operational Effectiveness and Operational Suitability Including "-ilities"
- Provide Information on Organization, Personnel Requirements, Doctrine and Tactics
- Verify Operating Instructions, Software Documentation, Publications and Handbooks

Conducted by:

- Operational Test Agency (OTA) Which Is Independent of Contractor and Development Agency
- Accomplished by Typical Operational and Support Personnel Expected to Use and Maintain Deployed System

Testing Environment:

- Realistic Operational Environment Including Enemy Counter-Measures When Possible

OT&E DEFINITIONS

OPERATIONAL EFFECTIVENESS

- The overall degree of mission accomplishment of a system when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, survivability, vulnerability, and threat.

OPERATIONAL SUITABILITY

- The degree to which a system can be placed satisfactorily in field use with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistics supportability, natural environmental effects and impacts, documentation and training requirements.

OPERATIONAL EFFECTIVENES VS OPERATIONAL SUITABILITY

***The Degree to Which a System Performs When Operated by the Service Members Who Were Trained to Operate It With Consideration Given to*:**

- **Organization**
- **Doctrine**
- **Tactics**
- **Survivability**
- **Vulnerability**
- **Threat**

***The Degree to Which a System Can Be Placed Satisfactorily in Field Use With Consideration Given to*:**

- **Availability**
- **Reliability**
- **Maintainability**
- **Interoperability**
- **Compatibility**
- **Logistics Supportability**
- **Transportability**
- **Documentation**
- **Manpower Supportability**
- **Training Requirements**
- **Safety & Human Factors**
- **Environmental Impacts**
- **Wartime Usage Rates**

COMMON TEST VARIABLES

OPERATIONAL EFFECTIVENESS:

- Organization
- Doctrine
- Tactics
- Survivability
- Vulnerability
- Threat

OPERATIONAL SUITABILITY:

- Availability
- Reliability
- Maintainability
- Logistics Supportability
- Transportability
- Documentation
- Manpower Supportability
- Wartime Usage Rates

COMMON AREAS:

Interoperability
Compatibility
Training Requirements
Safety
Human Factors
Environmental Impacts

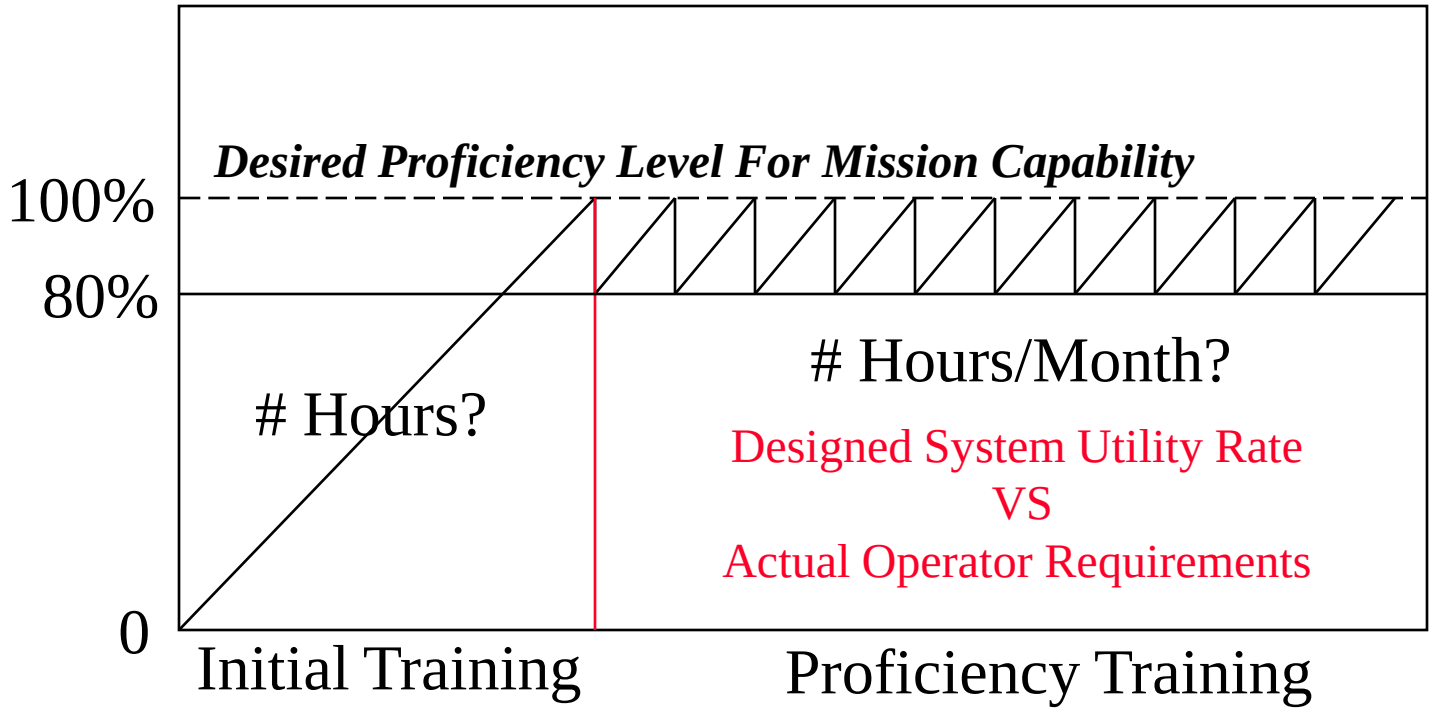
O&S COST DRIVERS

QUESTION: What is occurring during the O&S phase of a weapon system that drives the 65% or more of its Total Operating Costs?

Peacetime Answer: Training

Wartime Answer: Warfighting

TRAINING REQUIREMENTS



MISSING VARIABLES

- Peacetime OPTEMPO
- System Attrition Rates

MIXED MESSAGES

"In its own independent assessment, the DOT&E judged the MV-22 operationally effective but not operationally suitable, primarily due to concerns over the aircraft's reliability, maintainability, availability and interoperability."

Osprey Facts
Volume 11, Issue 13
December 8, 2000

Huh???? What's that mean to me in terms of mission capability?

Thom Crouch
January 22, 2004

ALTERNATIVE SOLUTION

Instead of assessing a weapon system in terms of Operational Effectiveness and Operational Suitability with and associated cost factor provided from another organization. Why not assess a system, or system of systems, in terms of:

Mission Capability and Affordability

Derived from a joint cooperative effort of both T&E and Cost Agencies

MISSION CAPABILITY

DERIVED FROM:

***OPERATIONAL EFFECTIVENESS*:**

- **Organization**
- **Doctrine**
- **Tactics**
- **Survivability**
- **Vulnerability**
- **Threat**

COMMON AREAS:

- **Interoperability**
- **Safety**
- **Compatibility**
- **Human Factors**
- **Training Requirements**
- **Environmental Impacts**

***OPERATIONAL SUITABILITY*:**

- **Availability**
- **Reliability**
- **Maintainability**
- **Logistics Supportability**
- **Transportability**
- **Documentation**
- **Manpower Supportability**
- **Wartime Usage Rates**

Plus:

- Peacetime Usage Rates
- System Attrition Rates

MISSION CAPABILITY EXAMPLE 1

Organization
Doctrine
Tactics

Analysis from these areas suggest that 6 systems are required to fulfill unit mission capability

Availability: 75%

Reliability
Maintainability
Logistics Supportability
Documentation
Manpower Supportability

Projected at 100% of annual O&S Budget

6 MC Systems / Availability Rate (75%) = 8 Systems Per Unit

Survivability
Vulnerability
Threat

Establish annual attrition rates for replacement consideration

FULLY MISSION CAPABLE AT BUDGET

MISSION CAPABILITY EXAMPLE 2

COST & MISSION CAPABILITY ARE DIRECTLY RELATED

Remains Fixed →

Organization
Doctrine
Tactics

Analysis from these areas suggest that 6 systems are required to fulfill unit mission capability

Availability: 65%
Reliability
Maintainability
Logistics Supportability
Documentation
Manpower Supportability

Projected annual O&S Budget only supports 65% Ao

8 Systems Per Unit X Ao Rate (65%) = Only 5 MC Systems Per Unit

Survivability
Vulnerability
Threat

Establish annual attrition rates for spares consideration

Option 1 – 5/6 MISSION CAPABLE AT BUDGET – OR-
Option 2 – FULLY MISSION CAPABLE AT 125% BUDGET
(or whatever cost factor is required to obtain 75% Ao)

TOTAL OWNERSHIP COST KPP

"As with other KPP, the TOC KPP would be considered as a mandatory threshold and the use of other tools and techniques would then serve to reinforce the importance of TOC. As KPP are also part of the Acquisition Program Baseline, TOC would receive attention from decision-makers at every level, throughout the developmental process."

NPS-AM-03-004
Acquisition Research Sponsored Report Series
Reduction of Total Ownership Cost
30 September 2003
M.W. Boudreau
B.R. Naegle

KPP PARAMETERS

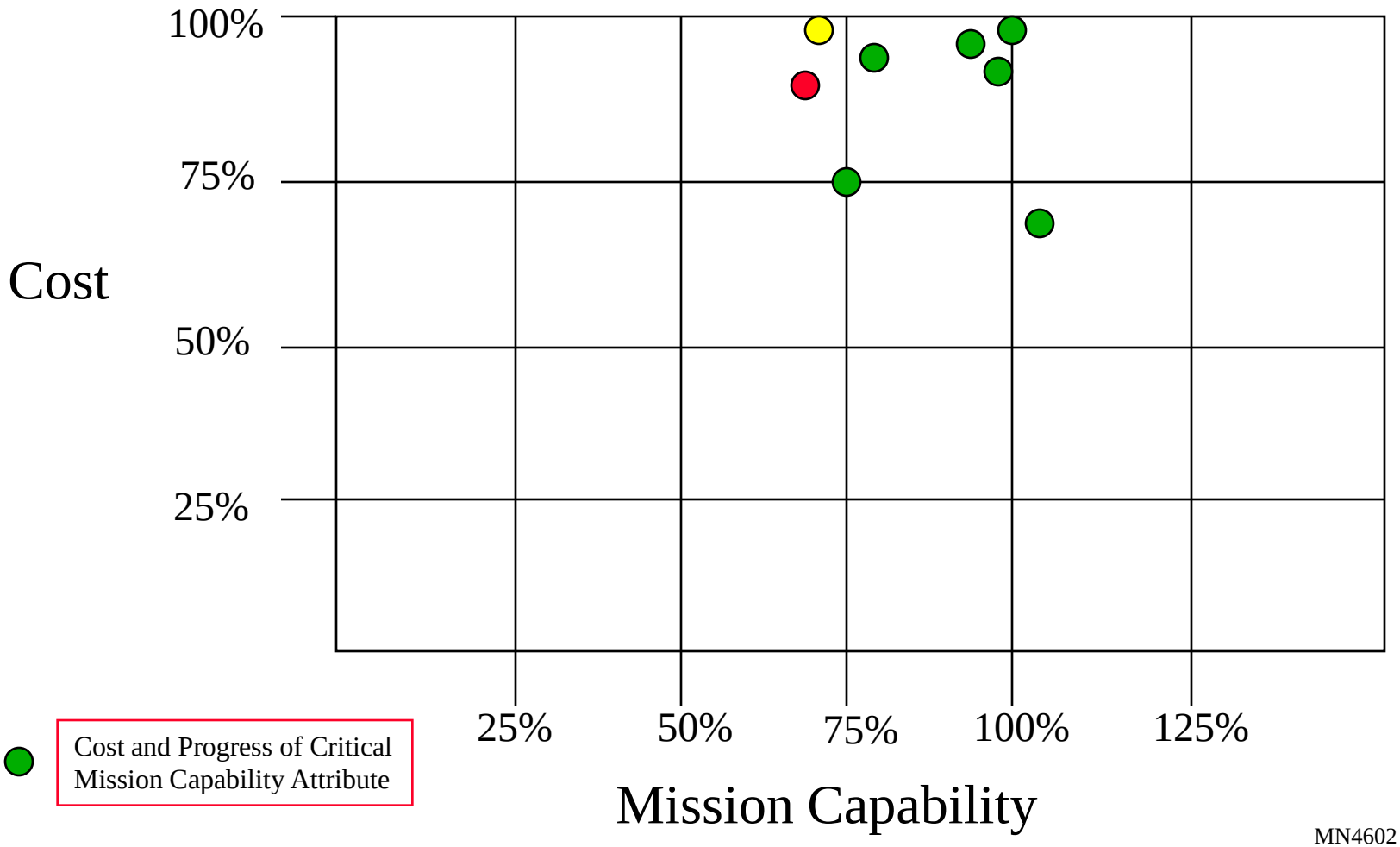
CJCSM 3170.01 – 24 JUNE 2003

"KPPs are those system attributes considered most essential for an effective capability. The CDD and the CPD contain only those few KPPs (generally eight or fewer) that capture the minimum operational effectiveness and suitability attributes needed to achieve the overall desired capabilities for the system(s) during the applicable increment."

"The following questions should be answered in the affirmative before a performance attribute is selected as a KPP: 1) Is it essential for defining the required capabilities? 2) Does it contribute to significant improvement in warfighting capabilities? 3) Is it achievable and affordable? *4) Is it measurable and testable?* 5)Is the attribute supported by analysis? 6) Is the sponsor willing to consider canceling or significantly restructuring the program if the attribute is not met?"

MISSION CAPABILTY & COST

Mission Capability is directly related to Cost and Affordability



RESEARCH QUESTIONS

P: How well do current DoD test methodologies support assessing a weapon systems true cost and performance characteristics?

A: Not very well and as noted in the V-22 case their ambiguous results can further confuse decision makers. Testing and quantifying results in terms of mission capability and affordability provides decision makers with a much more accurate portrayal of a system's status.

S1: Can/should cost, operational effectiveness and suitability be assessed independent of one another?

A1: No, it can be shown that operational suitability has a direct impact on operational effectiveness. It should also be noted that operational effectiveness and operational suitability share several common variables so how can they truly be independent of one another.

S2: Do current test methodologies adequately address weapon systems total ownership cost (TOC)?

A2: Cost organizations such as the CAIG generally do a fair job of estimating the overall cost of a program but are generally countered by PMO estimates that are much more optimistic. Since neither estimate is directly linking their estimates to actual O&S cost drivers, such as required training hours to support desired mission capability, decision makers generally side with the more optimistic of estimates to rationalize their judgment. There appears to be welcomed degree of maneuverability to make decision within a process that generates such ambiguous results. Having more accurate test results would mean having to make the tough decisions.

S3: Are there critical cost and performance variables absent in DoD's current evaluation logic?

A3: Yes, peacetime OPTEMPO rates supporting requisite levels of training to sustain mission capability skills are not being evaluated. Also, attrition rates due to crashes and accidents need to be taken into account to retained planned levels of mission capability.

S4: Are there different test methodologies that might be better suited for the testing of today's weapon systems?

A4: Yes, designing and executing operational tests in terms of mission capability and affordability will provide decision makers with a much more accurate portrayal of a system's status. The question still remains as to whether or not decision makers want to be impregnated with this degree of accuracy.

BACKUP SLIDES

AVAILABILITY

- ***A Measure of the Degree to Which an Item Is in an Operable and Committable State at the Start of a Mission When the Mission Is Called for at a Random Time.***
- **AVAILABILITY PARAMETERS**

$$Ao = \frac{\text{Total Uptime}}{\text{(Total Uptime + Total Downtime)}}$$

- **or:**

$$Ao = \frac{\text{Number of Systems ready}}{\text{(Number of Systems possessed)}}$$

- **or:**

$$Ao = \frac{\text{Operating Time + Standby Time}}{\text{Operating Time + Standby Time + Total Corrective Maint.Time + Total Preventive Maint.Time + Total Admin Logistics Downtime}}$$

AVAILABILITY KEY POINTS

- System Availability Is Difficult to Measure During Short OT Periods
- When Supply Support Is Limited or Non-Representative Use Achieved Availability (A_a):

$$A_a = OT / (OT+TCMT+TPMT)$$

- Plan for Logistics Realism
- System Standby Time Should Be Reasonable
- Availability & Reliability May Be Traded off for Some Systems
- Mode Transitions After Standby Time Should Be Evaluated
- Define: Full Mission-Capable (FMC), Partial Mission Capable (PMC), and Not Mission Capable (NMC) Prior to Tests

RELIABILITY

- ***The Duration or Probability of Failure-Free Performance Under Stated Conditions*.**
- **MISSION RELIABILITY:**
  - **The Ability of an Item to Perform Its Required Functions for the Duration of a Specified Mission Profile, or**
  - **The Probability of Success for Single-Use Items, Such As Rounds of Ammunition.**
- **PARAMETERS:**
  - **Probability of completing a mission**
  - **Mission Reliability = # of hours without a critical failure, under specified mission conditions**
  - **Probability of Success = # Successes / Total # attempts**
- **Others:**
  - **Mean Time Between Operational Mission Failure**
  - **Mean Time Between Mission-Critical Failures**
  - **Mean Time Between Unscheduled Maintenance**

RELIABILITY KEY POINTS:

- MTBF Usually Part of DT Spec, Use Operational Definitions
- Define Reliability Parameters Early in Program
- Short Test Periods May Not Identify "Wear-Out' Factor
- Software Reliability Is Always an Issue
- Do Not Use Reliability Growth Projections As Part of OT

MAINTAINABILITY

- ***The Ability of an Item to Be Retained in or Restored to Specified Condition When Maintenance Is Performed by Personnel Having Specified Skill Levels, Using Prescribed Procedures and Resources, at Each Prescribed Level of Maintenance and Repair.***

Maintainability Parameters

$$\text{MOMFRT} = \frac{\text{Total Number of clock hours of corrective, on-system, active repair time used to restore failed systems to mission-capable status after an Operational Mission Failure}}{\text{Total Number of Operational Mission Failures}}$$

$$\text{MCMT} = \frac{\text{Total Number of clock hrs of corrective, on-system, active repair time due to all Corr Maint}}{\text{Total \# of incidents requiring Corr Maint}}$$

$$\text{MTTR} = \frac{\text{Sum of Corr Maint Times}}{\text{Total \# of Corr Maint Actions}}$$

MAINTAINABILITY KEY POINTS:

- Maintainability Measurement Requires a Reasonable Number of Maintenance Events
- OT&E Maintainability Demonstrations must be Realistic
- Check Built-in Test Equipment for False Alarm Rates
- Scheduled Maintenance Time should be Examined
- Off-Equipment Repairs should be Evaluated (Poor Trouble-shooting)

INTEROPERABILITY

- ***The Ability of the Systems, Units, or Forces to Provide Services to and Accept Services From Other Systems, Units, or Forces, and to Use the Services So Exchanged to Enable Them to Operate Effectively Together***

PARAMETERS:

- **Usually Evaluated in Qualitative Manner**
- **Check Systems That Operate Simultaneously**
- **Check Systems Whose Modes Must Be Changed When Operating With the Tested System**

INTEROPERABILITY KEY POINTS:

- **Companion Systems Need to Be Identified Early in TEMP**
- **Consideration Should Be Given to Other Companion Systems Under Development**
- **Maturity of Supporting or Companion Systems Must Be Understood**
- **Determination of Adequate Suitability Depends on the Performance of the Supporting Systems**

COMPATIBILITY

- ***The Compatibility of Two or More Items or Components of Equipment or Materiel to Exist or Function in the Same System or Environment Without Mutual Interference*.**

PARAMETERS

- **Includes Measurement of Both Physical and Functional Characteristics.**
- **Most Detailed Compatibility Testing Is DT, but Should Be Monitored by OT**
- **Physical - Pins, Connectors, Alignment, Dimensions**
- **Electrical - Voltage, Cycles, Power, Surge Limits**
- **Electronic - Frequencies, Modes, Rates, Control Logic, Telemetry**
- **Software - Formats, Protocols, and Messages.**
- **Hardware - Conventions, Standards, Timing, Sequencing, Sensing, Control Logic**
- **Data - Rates Inputs, Characters, Codes**

COMPATIBILITY KEY POINTS:

- DT Results May Help Focus OT Planning
- Early Operational Testing May Uncover Compatibility Problems
- Nominal Operations May Not Expose Incompatibility Problems
- Special Resources for Compatibility Testing Must Be Identified Early
- Compatibility of Procedures Can Be a Factor in System Performance
- Modifications or Upgrades May Introduce Compatibility Problems

LOGISTICS SUPPORTABILITY

- ***The Degree to Which System Design Characteristics and Planned Logistics Resources, Including Manpower, Meet System Peacetime Readiness and Wartime Utilization Requirements.***

- **PARAMETERS:**
  - **Usually Evaluated in a Qualitative Manner**

LOGISTIC SUPPORTABILITY KEY POINTS

- Early ILS Planning Can Be Assessed As Part of the Evaluation, Including LSA, COI'S, and Support Concept.
- The ILSP Should Be Assessed, M&S May Be Used
- Operational Test Data Should Be Compared to the ILS Planning Factors
- Test Planning Must Address the Support for the Items Under Test
- Supportability of Software Should Be Considered
- Supply Support During OT May Be Unrealistic

TRANSPORTABILITY

- ***The Capability of Material to Be Moved by Towing, Self-Propulsion, or Carrier Through Any Means, Such As Railways, Highways, Waterways, Pipelines, Oceans, and Airways.***

PARAMETERS:

- **Are Provisions for Handling and Transporting the System Available?**
- **Can the System Be Transported to the Theater by the Preferred Means?**
- **Can the System Be Moved Adequately Within the Theater of Operations?**
- **Are the Dimensions and Weight Within the Required Limits of All Modes of Transportation?**

TRANSPORTABILITY KEY POINTS

- Unique Transportability Requirements Should Be Identified
- Transportability Should Be Verified As Part of OT
- All Projected Areas of Operations Should Be Part of the Assessment
- Transportability Should Include Movement Into Combat Locations
- Testing of Systems After Being Transported Can Be Critical for Some Systems

DOCUMENTATION

- ***For OT&E, Documentation Comprises Operator and Maintenance Instructions, Repair Parts Lists, and Support Manuals, As Well As Manuals Related to Computer Programs and System Software***

PARAMETERS

- **Evaluation Is Primarily Qualitative in Nature**
- **Some Quantitative Parameters Available Are:**
  - **Percent of Critical Tasks or Procedures Available**
  - **Percent of Critical Tasks or Procedures Validated**
  - **Percent of Erroneous Procedures or Tasks**

DOCUMENTATION KEY POINTS

- Documentation Should Be Available for the OT
- Assessment of Documentation May Be in a Separate Test Phase
- Testing Should Stress Use of Typical Military Skills, Tools, Facilities, and Support Equipment
- Only a Sample of the Operation, Maintenance, and Support Tasks May Naturally Occur in OT

MANPOWER SUPPORTABILITY

- ***The Identification and Acquisition of Military and Civilian Personnel With the Skills and Grades Required to Operate and Support a Materiel System Over Its Lifetime at Peacetime and Wartime Rates***

PARAMETERS

- **The Number of Personnel Required to Man a System When It Is Employed, Including:**
  - **Crew Size: Numbers of Specialties and Skill Levels Required to Operate and Maintain As System**
  - **Maintenance Ratio: The Ratio of Maintenance Manhours Per Operating Hour or Life Unit**

MANPOWER SUPPORTABILITY KEY POINTS

- Assessment Includes Examination of the Operating Crew
- Deficiencies May Reside in Other Suitability Areas
- Watch Out for "Golden Crews"
- Skill Levels and Numbers May Be Hard to Evaluate
- Proper Manning Levels for Systems Are Critical for Efficient Operations

TRAINING REQUIREMENTS

- ***Training and Training Support Include the Processes, Procedures, Techniques, Training Devices, and Equipment Used to Train Civilian and Active Duty and Reserve Military Personnel to Operate and Support a Materiel System***

Includes:

- Individual and Crew Training
- New Equipment Training
- Initial, Formal, and on-the-Job Training
- Logistics Support Planning for Training Equipment and Training Device Installations

PARAMETERS

- **Training Effectiveness Is Based Both Training Programs and Individual Performance**
- **Criteria May Differ Between Peacetime and Combat**
  - **“Critical Tasks Demonstrated" Is Ratio of Critical Tasks Demonstrated Within Time Standard Versus Number of Tasks Attempted**

TRAINING KEY POINTS

- OT Planning Must Address When the Training Program Will Be Available
- OT Planning Must Recognize the Interrelationships of Training, Documentation and Human Factors
- Training and OT Tasks Should Be Correlated
- Watch for Awkward or Unusually Demanding Tasks

SAFETY

- ***Freedom From Those Conditions That Can Cause Death, Injury, Occupational Illness, Damage to or Loss of Equipment or Property, or Damage to the Environment***

HAZARD CATEGORIES

Description	Category	Mishap Definition
■ Catastrophic	I	Death, or System loss
■ Critical	II	Severe Injury/Occupation Illness/Major Damage
■ Marginal	III	Minor Injury/Occupation Illness/Damage
■ Negligible	IV	Less than minor Injury/Illness/System Damage

HAZARD PROBABILITY LEVELS

Level	Probability Definition
• Frequent	Likely to Occur Frequently
• Probable	Will Occur Several Times in Item Life
• Occasional	Likely to Occur Sometime in Item Life
• Remote	Unlikely, but Possible to Occur in Item Life
• Improbable	So Unlikely That Assumed to Not Occur

SAFETY KEY POINTS

- Testers Should Be Sensitive to Any Potential for Significant Hazards
- Software Faults Can Result in Unexpected Hazards

HUMAN FACTORS

- ***Those Elements of System Operation and Maintenance Which Influence the Efficiency With Which People Can Use Systems to Accomplish the Operational Mission (Man-Machine Interface)***

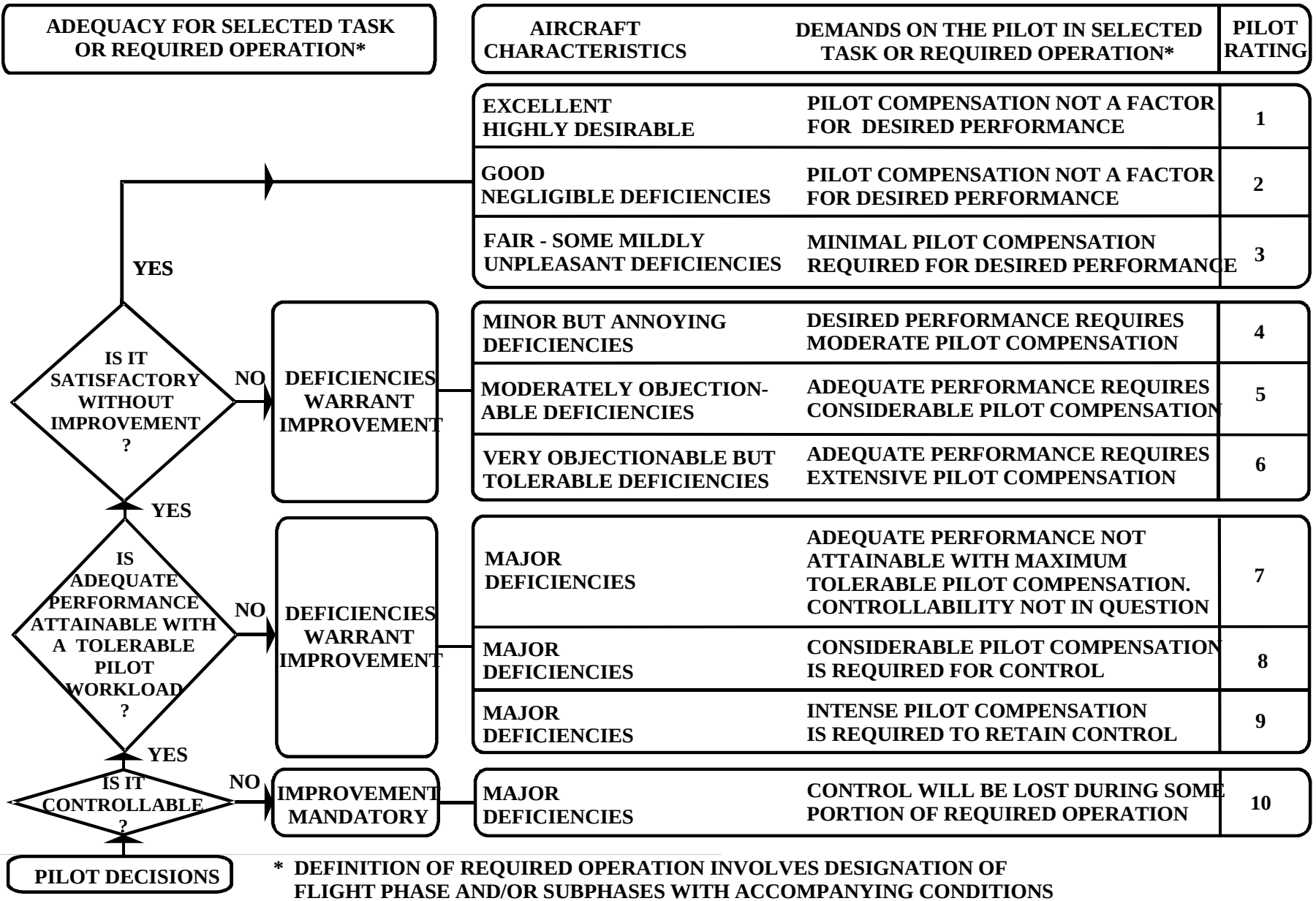
ELEMENTS INCLUDE:

- **Equipment Arrangement, Controls, and Displays**
- **Work Environment (Noise, Temp, Lighting)**
- **Task Complexity, Procedures, Fatigue**
- **Personnel Capabilities**

PARAMETERS

- **Qualitatively:** **Questionnaires, Interviews, Debriefing**
- **Quantitatively:** **Timed Tasks, Error Rates, Response Times, Accuracy**

HANDLING QUALITIES RATING SCALE



* DEFINITION OF REQUIRED OPERATION INVOLVES DESIGNATION OF FLIGHT PHASE AND/OR SUBPHASES WITH ACCOMPANYING CONDITIONS

HUMAN FACTORS KEY POINTS

- Address Both Operators and Maintenance Personnel
- Software Interface Should Be Assessed
- Physical Demands Should Be Assessed
- Advanced Display Techniques Should Be Identified and Evaluated
- Consider Entire Operating Environment
- Combat Stress Conditions Should Be Evaluated

OTHER OPERATIONAL SUITABILITY ISSUES

- SUITABILITY MODELING AND SIMULATION
- INTEGRATED DIAGNOSTICS
  - Percent of Correct Detection (P_{cd})
  - Mean Time to Fault Locate (MTTFL)
  - Percent Fault Isolation
  - Percent BIT False Alarm
- ENVIRONMENTAL FACTORS
  - Natural
  - Man-Made

OTHER OPERATIONAL SUITABILITY ISSUES (Cont.)

- **ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3)**
  - **Electromagnetic Interference (EMI)**
  - **Electromagnetic Compatibility (EMC)**
- **SOFTWARE SUPPORTABILITY**
  - **Products**
  - **Resources**
  - **Procedures**

A Framework for Discussing Environments

ENVIRONMENT	NATURAL (EXAMPLES)	MAN-MADE (EXAMPLES)
WEATHER	Rain, Snow, Winds, Sea State, Fog	-------
VEGETATION	Grass, Shrubs, Trees	--------
TERRAIN	Swamp, Desert, Mountains, Ice, Plains, Water, Soil	* Moats, Fox Holes, Tank Traps, Roads, Urban Features
ACOUSTIC	Thunder, Rain, Fish, Whales, Waves	* Decoys, Ships
ELECTRICAL / ELECTRONIC	Lightning, Solar Flares, Ionospheric Disturbances	* Jamming, EMP
ILLUMINATION	Sun, Moon, Eclipse	* Flares, Searchlights
CBR	Space Radiation, Epidemics	* Nuclear Radiation, Germ Warfare, Toxic Gasses
***BATTLEFIELD*:**		
SMOKE	Vegetation, Fires	Target Hits
DUST	Dust Storm	Bomb Blast
DIRT, SAND	Sand Storm	Bomb Blast
OBSCURANTS	Clouds, Rain, Fog, Snow, Haze, Sand, Dust	* Smoke Canisters, Flares, Battle Dust and Debris